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ON SOME SECONDARY SEXUAL CHARACTERS IN THE MALES OF CERTAIN INDIAN MOTHS

By H. Eltringham, D.Sc., F.R.S.

[Read 18th November, 1936.]

With Plates 1–3.

On several previous occasions, when describing histological structures I have appealed to collectors for material in a state of preservation adapted to similar research. My indebtedness, and that of Entomology in general, to the many kind friends who have assisted in this way, has lately been greatly increased by the generosity of one of our Fellows, Mr. D. G. Sevastopulo of Calcutta, who supplied a collection of moths representing some twenty-two species, carefully named, fixed, and packed in tubes. Probably no single collection of insects has revealed such a wealth of curious structures. The work of examination has occupied many months and involved the preparation of many thousands of sections and other microscopic preparations.

Ever since the publication of the late Fritz Müller's papers, about 1877, our knowledge of the brush-organs and similar male appendages in insects has been extending. This knowledge is, however, mainly confined to their form. From the observations of Lamborn and Carpenter a little is known about the epigamic use of the brushes and dust apparatus in certain Danaine butterflies (1911, *Proc. ent. Soc. Lond.* **1911** : xlvi, 1912, *loc. cit.* **1912** : lxxxiii, 1914, *loc. cit.* **1914** : cxi) and from those of Latter, it is known that the scent from the male brushes in *Euploea* may attract females from a distance (1935, *Proc. Roy. Soc.* (B) **117** : 470). On the whole, however, knowledge of structure has far outrun that of function. The microtomist's work in the laboratory must be supplemented by patient observation in the field, and whilst the task is one of great difficulty, it should for that reason prove the more attractive for those who have the qualifications for attempting it.

Whether all the organs described in this paper are scent-organs is at least unproved. Where, as in so many examples, dust-hairs are produced, there would seem to be no doubt on this point, but many of the brush-organs show remarkably little glandular structure, and the source of their impregnation, if any, is still obscure. In many species there are at least two apparently independent sets of organs. When describing an example of this kind in *Opsiphanes cassiae lucullus* (1929, *Trans. ent. Soc. Lond.* **77** : 1) I made the tentative suggestion that the products of the different organs might, by some nascent chemical action, produce, when mingled, the characteristic scent of the species. This explanation seems less applicable to many of the species here described, and one is led to think that the scents produced may have more than one function.

I am reminded of Longstaff's words at the conclusion of his well-known work, *Butterfly hunting in many Lands*, "Each discovery does but open to our view new domains of the unknown, . . . so that if we are honest, we must admit the truth of the paradox, that every addition to our knowledge does but increase the vastness of our ignorance."

Technique.

The material had been fixed in one of the Mercury Bichloride fixatives, though it had not been entirely cleared of the Mercury by subsequent treatment with Iodine, and there was a considerable deposit in the tissues. Fortunately it was found to be entirely removable by soaking in an alcoholic solution of Iodine, though in some instances the treatment had to be prolonged for several days, a treatment to be avoided if possible, since long exposure to Iodine may undo some of the previous fixation. The use of the fluid named "Solvax," supplied by Messrs. Flatters & Garnett, has enabled me to dispense with strong alcohol, benzol, cedar oil, and similar reagents, all of which tend to harden chitin. Solvax will dehydrate rapidly from 20% alcohol and mixes freely with paraffin and with xylol. It is an ideal medium for embedding purposes. I have occasionally used the Iron Haematoxylin method of staining, but have obtained very good and rapid results with Mann's Eosin-Methyl-Blue, differentiating with Dobell's fluid (*see* Eltringham, 1930, *Histological Methods*: 76). This method applied to sections of some of the organs described has produced a high degree of differentiation and some exceedingly beautiful preparations.

The order in which the species are described is merely that in which I dealt with them. The numbers in brackets after each specific name correspond with Hampson's numbers in *The Fauna of British India.*

Mr. W. H. T. Tams has kindly assisted me in identifying one species, the nomenclature of which was rather doubtful.

Glyphodes bivitralis Guen. (5038).

This little moth, of which only two specimens were available, has a pair of extrusible, or at least erectile, brushes on the prothorax. It would seem that scent-brushes may appear on almost any part of the body of an insect. They are found on the abdomen of many Lepidoptera, and also on the wings. I have described them on the heads of Trichoptera (1919, *Trans. ent. Soc. Lond.* **1919**: 420). Plate 1, fig. 1, is a side view, much magnified, of the anterior part of *bivitralis*. The brush is of the ordinary type, very similar to those found in Danaine butterflies. It is marked *b* in the drawing and arises from a membranous bag, *m*, and in repose the hairs of the brush seem not to be withdrawn into the bag, as they are in most brushes of this type, but lie, bent at an acute angle with the bag, in a fold of chitinous and much scaled tissue, just behind the head. Plate 1, fig. 3, is a sketch of what may be supposed to be the appearance when the brushes are fully expanded, though in neither of the examples available was it preserved in this position. The brush itself does not appear to be glandular, though in structures of this kind it is not always easy to distinguish between glandular and active trichogenic cells. The hairs arise from sockets of the usual type, each communicating with an active cell, showing in stained preparations a conspicuous nucleus. The hairs call for little remark. They are faintly fluted and very thin-walled, the latter feature being rather characteristic of brushes which secrete their own scent material. If the cells adjacent to the hair-sockets are not glandular, it is difficult to decide whence comes the secretion which the brushes are assumed to diffuse. In the fold in which the brush lies, there is a small patch of tissue, a section of which is shown at fig. 2. Whilst the fold itself is generally concave to accommodate the brush, this patch has a convex surface and is covered with scales. These can be seen in section on the upperside of the figure. A

double layer of cuticle lies beneath the scales, and between the two layers there is a small mass of tissue which may conceivably be the source of the scent material, though its structure is not of any glandular type with which I am familiar. It appears to be divided into separate cells, and these stain darkly near the outer surface. They contain many small elongated vesicles, which look like cracks in the cytoplasm, but there is no granulated structure such as one would expect in a secreting cell, nor are nuclei clearly defined.

Two separate pairs of scent-organs in the same insect are by no means unknown, but the second pair of organs in *bivitralis* are of a type hitherto unknown to me, though having certain slight analogies with those of *Lithosia griseola* (1935, *Trans. ent. Soc. Lond.* **83** : 7). At the extremity of the abdomen there is a mass of stiff black hairs, separable along the median line into two external brushes. The hairs arise partly from the basal end of the segment, and partly from a membranous process lying on the outer side of the clasper. Between this membrane and the clasper there is a large brush consisting almost entirely of "dust-hairs," *i.e.* hairs which readily break up transversely into minute particles to form a fine dust, presumably impregnated with a scent material. The occurrence of hairs of this type is not uncommon. The first reference known to me is that of the late Fritz Müller (1878, *Arch. Mus. Nac. Rio Janeiro*, **3** : 41). Müller found what he called articulated hairs in the costal folds of certain HESPERIIDAE. I described similar structures in the brushes of Danaine butterflies (*loc. cit. supra*) and also in the moth *Lithosia griseola* above referred to. It was some time before I could discover a probable source of any secretion which might impregnate the dust-hairs in *bivitralis*. They appear to be in the clasper. Plate 1, fig. 6, is a drawing of this organ as it appears slightly stained, cleared, and mounted whole. Between the two delicate cuticular surfaces there are many unicellular glands. Each has a socket like a scale socket, but there are few scales. Some give rise to hairs, but many appear to open on the surface through the now scaleless socket, an arrangement which is familiar in the wing-glands of Danaine butterflies. At fig. 4, I have drawn a few fragments of the dust-hairs. The whole brush is very voluminous and must contain many thousands of these hairs. Three principal types occur, though there are intermediates and the forms merge more or less into one another. There are hairs of large diameter without any cross-striation near the base, though the signs of transverse cleavage begin to appear more distally. There are hairs of medium size, with marked cross-striation which develops distally into actual cleavage, though intermediately each particle or segment is attached to the next by a fine filament, and finally there are extremely fine hairs, continuous proximally, but breaking into very fine dust in the distal parts of the brush. The diameters of the hairs vary from about ·003 mm. to ·008 mm. The whole "powder-puff" is more complicated than any I have so far observed. The respective uses of the two different sets of organs in this species remain to be discovered.

Glyphodes bicolor Swains. (5046).

This species has no thoracic brushes, but shows a development of dust-hairs in the abdomen, and glands in the clasper, similar to those in the previous species. The differences hardly warrant separate figures, but the dust-hairs are of a slightly different form, the segments into which they break having concave sides, giving them a bilobed appearance. The clasper differs in having more closely packed gland-cells, forming in some areas a continuous

tissue, whilst instead of hairs there are tufts of scales especially at the terminal edges. These scales are faintly striated and have a heavily granulated surface. They may be porous, but very minute pores in such organs are always difficult to determine with certainty, owing to the similarity, under a high power, of pores and nodules.

Glyphodes indica Saund. (5054).

The extremity of the abdomen of this species has a pair of very beautiful brushes formed from spatulate scales of differing lengths. I have illustrated the structure on Plate 1, fig. 5. In the inactive state they lie pressed against the sides of the abdomen. Each tuft arises from a cuticular projection, having at its apex a slight concavity. Whether these fan-like tufts are themselves glandular I am unable certainly to decide. The scales of which they are formed arise from a layer of darkly-staining and apparently active cells, a feature rather suggestive in itself, since the trichogenes of inactive scales are usually aborted. The claspers have many scent-scales arising from active cells, and there are very large dust-hair brushes similar to those in the species already described.

Glyphodes hilaralis Wlk. (5012).

Of this species I have had only one example and the brushes had been removed and sections made before I realised that the claspers might contain the glands. The outer black brushes are exceptionally large and are double as shown in Plate 1, fig. 9. The inner pair enclose dust-hair brushes as in the other species described. The trichogenic cells at the bases of both the ordinary and dust-hairs are active.

Glyphodes vertumnalis Guen. (5015).

This species has the usual large anal tuft and a great mass of dust-hairs. The fragments into which these break are very similar to those of *bivitralis*, but the connecting thread is, before separation, rather more conspicuous, so that the unbroken structure has a remarkable resemblance to a piece of cable-chain. The clasper is somewhat thickened along its lower edge, but does not show the glandular structure of that of *bivitralis*. The hind tibiae are provided with conspicuous brushes as shown in fig. 7, and there is a tuft of scales on the inner margin of the hind-wing. The significance of these features is obscure. Sections of the tibia and of the wing-tuft do not exhibit any structures which would warrant their being regarded as scent-organs. The modification of the hind tibia suggests a sense rather than a scent-organ, since there are groups of minute " sensory pits " on the chitin, but preparations of fresh material by one of the metallic impregnation processes would be necessary to confirm this hypothesis.

Glyphodes negatalis Wlk. (5010).

Only one example of this species was available. The distal extremity of the abdomen was sectioned, and the sections show so complicated a structure that further material is necessary for a complete study of the various parts. The claspers were too much disintegrated for an accurate reconstruction of their form. The whole armature is enclosed by two thin lateral plates or valves, bearing on the outer surface numerous elongated scales forming an outer brush. These plates are considerably thickened at the posterior ex-

tremity and between the walls of the thickened portion there are bodies which have the appearance of transverse sections of muscle, though the presence of muscle in this position seems improbable. Within these lateral plates there is a very voluminous mass of dust-hairs, which arise from sockets resting on a layer of active cells. The most remarkable feature of the apparatus is, however, an intermediate brush, in the form of a core embedded in the dust-hairs. The hairs of this brush are of comparatively large diameter (about ·01 mm.). The hair-walls are extremely thin, and quite obviously perforated by pores over a large part of their length. The surface is almost smooth, only the faintest striation being visible under a high magnification, and the distal ends are either pointed, or more frequently forked, having two or three prongs. Each hair arises from a socket, the base of which is surrounded by a mass of cytoplasmic material. The sockets rest on a layer of cells with large nuclei and plentifully supplied with tracheae. It is difficult to resist the conclusion that these hairs supply the impregnation for the dust-hairs. The latter differ slightly from those in other species described, in the fact that the particles into which they break are of smaller average size. I have not attempted to draw any of the sections, since an illustration based on only one point of view is liable to be misleading. At fig. 8, however, I have illustrated the terminal parts of some of the perforated hairs, which form the " core-brush." There is a small fork near the base of the antenna, ending in a tuft of hairs. I have made sections of this, but cannot find anything remarkable in its structure.

Sylepta lunalis Guen. (4989).

Between the outer cuticle and the claspers there lies a pair of large brushes, which do not, however, exhibit any remarkable features. The hairs arise from a layer of very active cells. There are no dust-hairs.

Amyna (*Ilattia*) *octo* Guen. (1834).

The armature and appendages of this species show the very complicated structure illustrated at fig. 10. The example is rather widely spread out and viewed from the underside. The central spindle-shaped object is the aedeagus, behind and around which is seen the outline of the uncus. The aedeagus is set with numerous spiny projections. On either side of the uncus there is a peculiar process covered with chitinous projections which when further magnified show the form illustrated at fig. 11. These projections rather suggest a many-fingered glove, but the number of " fingers " varies from six to twelve. They arise from sockets resembling a " ball " or " universal " joint. Following outwards from the centre line come the claspers which resemble folded leaves, and each has a long terminal process. Outside the claspers lies a pair of plume-like brushes, the fine hairs of which are curved inwards. Lastly at the base of each of these is a second, rather voluminous brush, arising from a convex, button-like mass of sockets. If there is any scent apparatus in this species it probably lies in the last pair of brushes. There is no dust apparatus nor any apparent evidence of glands.

Nanaguna breviuscula nigridisca Hamps.

One might say that the development of brush-organs in this species has run wild. Adequately to work out the histological structure of all its curious appendages would require many more than the two examples available.

Plate 1, fig. 12, is a sketch of a side view of the body of the insect as it lies in a watch-glass. Three lateral brushes are at once evident. A thoracic brush projects from a point just below the attachment of the hind-wing, and two more arise from the abdomen. They are composed of very fine hairs which lie flat on the preserved specimen but are probably erectile during life. I have been unable to find any glandular tissue associated with the thoracic brush. The anterior abdominal brush is curved round at its base, forming a kind of vortical cavity in the cuticle (Plate 1, fig. 12, *v*). This cavity is lined with extremely delicate, many-pointed scales resting on a layer of tissue, which although staining readily does not show a definitely glandular structure. The posterior abdominal brush shows no external peculiarity, but seems associated with the anal brushes in a rather complex way. If the anal segments are opened out and the armature removed, some idea of the relative arrangement of the parts can be obtained, though the resulting displacement precludes a correct representation of their position in the natural state. Plate 1, fig. 13, is a diagram which may help to explain the structures. At *a* there is a flat mass of long dark-coloured scales, and on either side of this lies an extrusible brush *b*, *b*. Somewhat anterior to the bases of these brushes there can be seen two small swellings *s*, *s*. These lie under the cuticle and adjacent to the bases of the posterior abdominal brushes *ab*, *ab*, already mentioned. On dissecting out one of these swellings it was found to consist of a very small auxiliary brush, formed from rather spatulate hairs or scales which show a slightly glandular structure at the sockets. The extrusible brushes *b*, *b*, have no glands, but at the base of the central pad *a*, there is a small quantity of tissue which may have secretory properties. The whole system is extremely complex and many sections in different directions would be necessary for a complete elucidation. The armature itself, not shown in fig. 13, is of the peculiar form shown in fig. 14, as seen from the underside. The uncus, *u*, is in the usual form of a hook, and has two small spines at its apex. The claspers are profoundly modified and seem to be represented by the two curved processes *p*, *p*. They are clavate and the thickened terminal parts are set with numerous minute spines. I have not found in any of the above described organs any well-marked glandular development. The hind-wing, on the contrary, has an unmistakable and well-developed scent apparatus. Plate 1, fig. 15, represents the upperside of the right hind-wing, and on the anterior margin there is a mass of hairs, lying on a patch of scent-scales, *p*. In this position there is an intermembranous layer of gland-cells, particularly numerous in the nervure and well supplied with nerves and tracheae. The underside of the fore-wing also has some special scales and hairs, in the corresponding position, with a slight glandular structure.

Argina cribraria Clerck (1275).

I mention this species here because a single example was included in the collection sent me, but I could find no special organs in or upon it.

Polydesma umbricola Bsd. (2423).

The thorax and legs of this moth are so thickly covered with masses of "fur," that it is difficult to distinguish between special organs and the specifically dense clothing of the cuticle. The only apparent scent-organ I have been able to find is a small lateral brush on the metathorax lying just ventro-anteriorly to the operculum of the tympanic organ. Plate 2, fig. 1, shows a

lateral view of this region. The tympanic organ is in the abdomen but its extended opening is covered by an operculum *o*, projecting from the metathorax. Just below the base of this there is a rather flat brush *b*, arising from a slightly plicate membrane. Sections of this organ show the structure illustrated at fig. 2, where the membrane, *m*, is set with scales, and in the lumen there is a small quantity of apparently rather shrunken tissue, *t*. This tissue has a faintly granular cytoplasm, many minute vacuoles, and a few darker particles which may be nuclei, but cellular structure is not very clearly defined. I am not at all certain that this tissue is glandular. To the right of the figure is the part of the membrane carrying the brush-hairs, the bases of a few of which are shown. Beneath the sockets is a layer of modified hypoderm *g*, which I take to be the glandular part of the brush. The legs of this moth are densely clothed with hairs, and the fore-legs especially are provided with immense tibial brushes. I have made sections of these, and find that the tibiae and a large tibial spine are studded with sensory pits. There is no glandular structure, and, as in *Glyphodes vertumnalis*, the whole apparatus seems to be sensory. The armature has none of the elaborate brush apparatus described in some of the foregoing species, but is nevertheless of a very remarkable form. I have shown a dorsal view on Plate 2, at fig. 3. The uncus, in the centre, is very slender, curved downwards, and of the usual form, but the claspers are highly modified. The small projections on each side of the uncus are difficult to represent in dorsal view, but they are rather of the shape of a cork-screw of extremely coarse pitch, while externally to these projections there are bunches of stiff, heavily chitinised spines, of which in the specimen figured there are four on one side and five on the other. Posteriorly and in the centre is seen the aedeagus sheath, but the aedeagus itself has been removed. It is about the same length as the whole of the rest of the organ, viz. about 8 mm., only about 2 mm. less than the entire length of the abdomen of the insect.

Remigia frugalis F. (2574).

This species has two very large brushes arising from the prothorax, just beneath the attachment of the fore-legs. Plate 2, fig. 4, shows a somewhat diagrammatic ventral view of the anterior part of the insect, the fore-legs being set back in a rather unnatural position, and other parts removed, to show the position of the two brushes. All the legs are densely clothed with hairs and scales, and the hind-legs are of rather unusual form, being evenly fringed with scales throughout their entire length, reminding one of the swimming legs of some aquatic insects. No doubt this feature is referred to in the generic name. Fig. 5 is a drawing of this leg. There seems to be no glandular structure external to the two prothoracic brushes, they are not extrusible from a brush-bag, but are doubtless erectile by direct muscular movement, though it is hardly possible from the preserved and contracted specimen to be sure of their appearance in the living insect. Sections of the brushes stained with Mann's stain show a rather complicated structure. Plate 2, fig. 7, illustrates the appearance of a single hair-socket under the $\frac{1}{12}$-inch objective. The hair, of which the basal part is shown at *h*, is thin-walled and very faintly reticulated, and probably permeable. It is inserted in a peculiarly massive chitinous socket *s*, the proximal parts of which are distended and reflexed in the form of lobes. The tubular part of this socket is filled with a mass of cytoplasmic material *ct*, which takes the blue element of the stain. This mass rests on a layer of cells *c*, which, for the most part, stain red. Nuclei are not well marked

but darker particles are sometimes seen. Below these cells is a thin cuticle, *cu*, which takes the blue stain. There seems little doubt that the brush provides its own secretion.

The armature though characteristically complex does not suggest the presence of any scent-organ, nor are there any special organs on the wings.

Thalassodes veraria Guen. (4106).

Of this species only one example was available. On removing the wings, on which there are no special organs, there appears to be a large glistening swelling on the coxa of the hind-leg. From an aperture in this, there protrudes what at first sight might almost be a congealed fluid. It is, however, a mass of extremely fine hairs, about ·001 mm. in diameter. Plate 2, fig. 6, is a drawing of this unusual modification of the hind-leg. The mass of fine hairs is seen protruding at *m*. At the junction of the coxa and femur there is a small tuft of scales, *h*, and the tibia has a large brush of rather stiff hairs, *t*. The fine hairs of the coxal organ are so easily detached that the greatest care is necessary in dissection. The opening in the coxal receptacle is bordered by a regular row of glistening scales, and on the side opposite to that shown in the drawing, the whole receptacle is outwardly scaled in a similar manner. I have made sections of the organ, and they show that the whole of the swollen part is filled with a dense mass of the fine hairs already mentioned. They arise from a trichogenic membrane studded with thousands of minute hair-sockets, and beneath the sockets there is a layer of small cells, resembling those found in the scent glands of wings. The scales which cover the outer surface of the organ lie on a somewhat thicker layer of vacuolated tissue, strongly suggesting a further source of secretion. There is little doubt that the fine hairs form a dust material, though there are no regular constrictions corresponding with points of fracture as in the usual dust-hair formation. There is a bundle of muscle fibres beneath the tuft, showing that it is probably extrusible by fluid pressure and can be retracted. Plate 2, fig. 8, represents a small part of the cellular membrane, and the basal parts of a few of the slender hairs.

On dissecting out the armature, and viewing it from the ventral side, there can be seen a pair of ventro-lateral brushes, arising at the base of the vinculum, and if one of these be removed entire with its attachments, it is found to contain as a core a membranous bag. This is turned on itself in a multiplicity of folds and the hairs arise from what, if it were fully expanded, would be the outer surface of the bag. Fig. 9 shows the basal parts of two of the hairs with their peculiar attachment to the membrane. There is no very obvious socket. The rugose membrane swells out suddenly and is attached to the hair. Just at the base of the hair there is a small mass of protoplasmic material which stains bright red with Mann's stain, while the membrane stains blue. In some places this red-staining substance extends inwards in the form of a rod. The whole structure presents a very complex appearance in its retracted state, but it suggests that when the organ is protruded by internal fluid pressure, it would present the form, not of an ordinary extruded brush, but of a small balloon, covered rather sparsely with hairs.

Nephopteryx paurosema Meyr. (4363).

On the underside of the hind-wing of this species there is a complicated organ represented on Plate 2, fig. 10. In the preserved example the whole

apparatus is so tightly rolled up that it is not easy to unfold it without damage, nor with the single specimen available has it been a simple matter to identify the various parts in section. The whole wing is about 7 mm. long. Near the base there is a little tuft of spatulate scales, *t*, arising from a small stalk. Beyond this the wing-membrane is very deeply folded. The fold is lined with numerous broad glistening scales, and contains a brush, *b*, of long spatulate scales. The inner margin is also thickly scaled. On the nervure *n*, there is a flat fold which projects from the upperside of the wing. I have not been able to indicate this in the drawing. Owing to the complex folding of the membrane, sections present a rather confused appearance. It is, however, possible to identify the principal structures. The scales of the tuft *t* are not remarkable. They arise from ordinary sockets, beneath which there is a small quantity of cytoplasmic material. The brush *b* is formed of very long scales of rather variable shape. Many are flat and broad throughout their entire length, though broadest at the distal ends. Others are very narrow except at the distal end where they are widened to a paddle-shaped extremity, the edges of which are folded over, in the manner suggested in fig. 11. In many places the cuticle of these scales is perforated by minute pores, though as there is little or no glandular material in their sockets, I cannot regard the scales themselves as secretory. Assuming the whole apparatus to be a scent-organ, the secretion must be supposed to come from the small flat scales lining the wing-fold in which the brush lies, since the sockets of these communicate with numerous intermembranous glands, of the kind commonly found at the bases of scent-scales.

The armature is so complicated that I have not ventured to illustrate it from the single example available. Adequate description would almost require the construction of a model built up from a series of dissections of several specimens. The claspers are long and the ventral edge is densely covered with glistening scales. On each side is a long brush, but the most unusual feature is a kind of secondary armature comprising two pairs of complex chitinous structures, all of which arise from the bases of the main claspers.

Cnaphalocrocis medinalis Guen. (4814).

This little species has an organ on the costal region of the fore-wing, a scale-tuft on the fore-leg, and two very slender brushes arising from the base of the armature. Plate 2, fig. 12, is a diagram of a partly cleared fore-wing. The costa is densely scaled, and above the end of the discoidal cell there is a double row of large curved scales. In the cell there is a small " brand " of short narrow scales. A stained wing mounted flat and examined under a high power shows numerous very small unicellular glands, especially plentiful about the nervures. The whole structure suggests a mass of scent-scales or " androconia," of the type now well known in many Lepidoptera. Sections of the wing show very little as the gland-cells are so flat that they become inconspicuous. Sections of the scale-tuft on the fore-legs show no glandular structure. The two small armature brushes are not themselves glandular, and if there is any secretion it would appear to come from the claspers, which are covered with large but very delicate scales, each arising from a socket, beneath which is a deeply staining body indicating the presence of an active cell. Along the edge of the clasper there is a row of hairs, the sockets of which are connected with a nerve fibre. All the nerve fibres proceed from a conspicuous nerve cord, and the whole arrangement forms a sensitive tactile organ.

I mention this feature especially in connection with this species as it is unusually distinct. I would, however, point out that all the claspers examined have a fairly complete nerve supply. Most of the thousands of male armatures which have been described and figured have been prepared by boiling in caustic so as to leave only the harder parts. One is thus led to think of the claspers as mere mechanical organs whereas they are well equipped with nerves, muscles, and tracheae, and are undoubtedly organs of complex structure and function.

Marasmia venilialis Wlk. (4815).

On the costa of the fore-wing there is a mass of scales and the area covered by them is much thickened, projecting as a swelling from the underside of the wing. The fore-legs have tufts, very similar in appearance to those of *medinalis*. There are two slender anal ventro-lateral brushes arising near the bases of the claspers, and between them a tuft of hairs, of about the same length. The brushes are not extrusible from a brush-bag, but are probably erectile. They do not appear to be self-secreting. If sections be made of the swollen area on the fore costa, it is seen, as in Plate 2, fig. 13, to be a concavity in the wing covered by a layer of large protective scales, *s*, and containing scent-scales, *sc*, and very fine dust-hairs, *d*. These are not more than ·001 mm. in diameter, and often less. They are not constricted at regular intervals, but seem readily to break, not into short dust-particles, but into spicules. They arise together with the scent-scales from a thin glandular intermembranous layer of the wing. It is not easy to suggest how the dust-hairs are diffused, unless possibly it is by rubbing with the feet. This type of organ has been known for many years, as already mentioned in the earlier part of this paper. Westwood, 1852, *Gen. diurn. Lep.*, observed it in HESPERIIDAE, and Herrich-Schaeffer, 1868, *Prodrom. Syst. Lep.*, referred to it as the " costal fold." It was Müller, however, who, as already stated, first found the " dust-hairs " in 1878.

The clasper, fig. 14, is not complicated but bears some interesting structures. The outer side is densely covered with hairs and the inner side has both hairs and scales, most of which point away from the posterior end. At *p*, there is a small process with a clavate extremity bearing several spines, each of which has a nerve-thread entering its base. At *s* there is a clothing of scales, all directed anteriorly, and of a form which is new to me. Three of them are shown much magnified at fig. 15. At the broad end there is a slight granulation, and just proximally to this there is a disc-like structure, also granulated. There do not appear to be gland-cells at the bases of these scales, and their function is not evident. There are numerous protoplasmic granules in the clasper, but they do not suggest the marked glandular formation found in some of the other species here described.

Botyodes asialis Guen. (4948).

There do not appear to be any special organs on the wings, thorax, or legs of this species, but a preliminary dissection of the distal end of the abdomen, made by cutting ventrally and turning back the overlying cuticle, discloses two large masses of scales, Plate 2, fig. 16, very closely packed, and lying against the outer surfaces of the claspers. These fall away at a touch and removal of the organ intact is almost impossible. Beneath this scale-brush there is a voluminous mass of dust-hairs, also very easily detachable. The outer scales are long, very delicate, and have a granulated appearance sug-

gestive of pores. They are almost certainly permeable. The dust-hairs vary somewhat in thickness, and for the most part do not break into separate nodules, but into slightly spindle-shaped groups of five or more segments, having the form shown at fig. 17. Owing to the tendency of the organs to disintegrate, and there being only one example available, I have been unable to secure a good whole section, so that it is difficult correctly to correlate the structures. The long scales of the outer layer arise from deep funnel-shaped sockets beneath which lie active cells closely associated with tracheae, as shown in fig. 18. The dust-hairs arise from correspondingly small sockets, but in most places the layer of cells beneath them is thicker, though the cells are smaller as in fig. 19. The transition from the thin layer of large cells to the thicker mass of small ones is not well marked. Whether both classes of cells are secretory, or one of them trichogenic I am unable to decide.

Lepyrodes neptis Cr. (5069).

The fore-legs are densely clothed with long hairs so that the tarsi are hidden by them and have the appearance of brushes. The mid tibiae are also covered with long scales. Sections of the fore tarsi and other parts of the legs, show no special structures, indeed there is a remarkable absence of cellular tissue. There is a peculiar organ on the underside of the metathorax (Plate 3, fig. 1). The illustration shows a view of the underside of part of the thorax after removal of the head and front legs. Parts of the metathoracic legs are shown.

Just below the attachment of the wings there are two small cavities *cc*, each having a narrow rim on the inner side coated with small scales. On the outer side there is a mass of large spatulate scales forming a cover for the cavity. In the cavity there is a minute tuft of a few small scales. Sections of this organ show only the very slightest development of cellular structure at the bases of the tuft and covering scales. Indeed there is little more than a thin membrane, with the usual scale sockets, and a few granules visible only under the highest powers. There is nothing to provide a clue to the function of this organ. The armature when dissected out has at first the appearance of bearing two slender brushes, but these are found to be merely long hairs or scales emanating from the outer surface of the claspers. The latter are of very simple structure without any remarkable appendages, but a stained example, mounted whole, shows a layer of cells between the outer and inner cuticle. Cells of this character are not unusual in the claspers of some of the moths examined. Plate 3, fig. 3, is a diagram of the clasper merely to show the position of the majority of these cells, which in the shaded area are somewhat thicker than elsewhere. Traces of them, much attenuated, can be seen over most of the area of the clasper. At fig. 2 I have shown a few of the cells more highly magnified. They are very irregularly pentagonal, though the sides may sometimes be rounded. There is a dark-staining centre from which several dark lines radiate. They may conceivably be modified fat-cells, though they lack some of the characteristics, notably the usual vacuolated appearance, of typical fatty tissue.

Crocidolomia binotalis Zell. (5076).

In this species there is a costal tuft of folded scales on the fore-wing, as shown in Plate 3, fig. 4, *t*. It does not contain dust-hairs as found in some of the other species here described. A wing stained, cleared and mounted,

shows no very noticeable intermembranous cellular development. If there are any secretory cells they must be very minute. If an insect be examined from the underside there is found, on the prothorax, an extremely complex apparatus, and fortunately several specimens were available, otherwise it would have been impossible to make anything like an exhaustive examination. By spreading out a specimen on a block of wax, under alcohol, and stretching the parts with small pins, I secured a preparation showing as much as can be seen in a single view. It is illustrated at fig. 5, though owing to the treatment described, the relative positions of the parts are considerably distorted. The " neck " has been extended to show the points of origin of the two brushes, *bb*. At *cc* are the coxae of the fore-legs. These normally lie pressed together and more or less parallel with the long axis of the body. Beneath the coxae, from the ventral view, there lie two delicate sheaths, *ss*. These really arise at the bases of the brushes. They are formed from a thin, rather " silvery " membrane, clothed with large but very delicate scales. In the inactive position the brushes lie in these sheaths, which are closely folded round them, but when unfolded, the sheaths are capable of opening along the whole of the outer side. The brushes are not extrusible from a bag, like those of a Danaine butterfly, but are erectile, and each has a small chitinous lever with a muscle attached thereto. If there is some doubt as to the glandular nature of some of the brushes already described, there is none in respect of the brushes of this species. Plate 3, fig. 7, shows, in section, a fragment of the basal part of one of them. In the drawing, *ch* is part of the erectile apparatus, and there appear to be two kinds of hairs, or at least hairs arising from two kinds of sockets. At *h* are the bases of a few hairs arising from very short sockets, and at *hh* there are hairs of which the sockets are long and trumpet-shaped. Both kinds have conspicuous gland-cells beneath them, and although in the particular preparation illustrated, the shorter sockets have the larger gland-cells, this is not so in all sections, and the depth of the gland-cells seems to vary, irrespectively of the form of the sockets.

The structures on the coxa are better described from fig. 6, which is drawn from a point of view slightly different from fig. 5, and under a higher power. On the inner ventro-lateral part of the coxa is a concavity *cy*, sparsely set with small dark-coloured scales, and basally from this there is a much deeper concavity *c*, covered by a peculiarly shaped object *p*. At first I took this to be a curiously-formed chitinous plate. It is actually a mass of curved scales, so tightly fitted together as to have the appearance of a continuous structure. The mass is easily detached entire, and only when attacked with needles is it found to be composed of scales. Beneath this shield the concavity contains a voluminous mass of extremely slender, spatulate-ended, scales or hairs, which do not break transversely, but are so numerous and delicate and so easily detached that they suggest the same sort of function as the dust-hairs found in other species here described, and seem especially comparable with the coxal brushes of *Thalassodes veraria*. A few of them are shown protruding at *sp*, fig. 6. Sections of the coxa, fig. 8, show an extreme complication which it would require more material than is at present available fully to elucidate. The plate-like mass of scales on the outer part of the cavity shows, in section, that its components surround the very fine inner tuft, in whorl-like formation. All the scales and hairs of the finer tuft arise from conspicuously glandular sockets. The fine scales of the inner tuft are of at least two forms. Both are broader at the basal part, and taper off into a kind of whip-lash form, but one type has a sharp bend in the broader part. I have shown the two

forms at fig. 9, but they cannot be drawn on this scale in true proportion as they are really very much longer in relation to their width. The whip-lash terminations are only about ·0005 mm. thick. The "plate" or "shield" scales are of a much stouter form, and many of these are also sharply bent, though they become wider distally, instead of narrower. At their distal ends they are sharply bent over to form a kind of locking device, which doubtless accounts for the difficulty of separating them. The armature is of a comparatively simple form, but in connection with it there are again two brushes, arising just proximally to the bases of the claspers. They are slender and present no very remarkable features. The claspers are simple and though there are a few cells along the upper and lower edges, they have more the appearance of a fatty than of a glandular structure.

Eurrhyparodes bracteolalis Zell. (4789).

There is no very elaborate apparatus in this little species but on the fore costa, rather distally placed, there is a swollen patch covered with curved scales. Plate 3, fig. 10, shows a transverse section of this organ. At *cn* is the swollen and distorted costal nervure, and at *cs* the curved scales which form a cover for the cavity, in which are seen at *dh* large numbers of dust-hairs, cut transversely. At *sc* are portions of scent-scales cut at various angles, but the glandular layer from which these arise can be clearly seen at *gl*. Longitudinally the dust-hairs have the appearance shown at fig. 11. They look like minute funnels strung together on a slender thread, and arise from curious forked bases, one of which is also shown. The diameter of the dust-hairs is about ·002 mm. The armature is of very simple character, and there appears to be a very rudimentary brush, consisting of a few hairs, arising at the base of each clasper.

Sameodes cancellalis Zell. (5082).

The fore-wing of this species is curiously shaped, owing to a sudden projection at about one-third of the length of the costa. This is found to be a tuft of coiled scales, in the cavity of which there are a few smaller scales. There are no dust-hairs, and if the enclosed structures are scent-scales, the glandular development is very inconspicuous. On the metathorax, just beneath the attachment of the hind-wing, there is a small brush. Sections of this show that the hairs arise from a much folded membrane, and the organ is probably erectile by fluid pressure from within, and collapsible by the contractile elasticity of the membrane. Here again I can find no very obvious secretory apparatus. A much more complicated structure is found at the end of the abdomen. Here on removal of the cuticular tissues, two large masses of black scales are found outside the claspers, forming voluminous brushes. On the outer side of these scales is a small brush of yellow hairs, and on the inner side, lying between the black scales and the claspers, there is a second brush of yellow hairs, which when dissected out, appears to be solid, at least at the distal end. Teased with needles the hairs can be separated, but they certainly adhere rather firmly, whether through a partial fusion, or because of some congealed secretion, I cannot certainly decide. The idea of partial fusion is suggested by a recollection of the peculiar clavate brush, described by me as found in our British species, *Lithosia griseola* Hübn. (1935, *Trans. R. ent. Soc. Lond.* **83** : 7), where the distal ends of the hairs are swollen and fused together. The formation in *cancellalis* may be an approach to that

condition. Plate 3, fig. 12, shows a reconstructed section of the brush apparatus, the armature, which normally lies in the central area having been removed. At *fb* are the two inner brushes, the hairs of which appear to be partially fused together. At *bb* is one of the very thick black brushes, and at *ob* the outer brush, which is comparatively small, *c* is the cuticle. All the brushes arise from a layer, *gl*, of distinctly glandular tissue. When the black brushes are teased out on a slide, they are found to consist of scales in every stage, from extremely thin plain hairs, through a ribbon-like formation, to a structure which has the appearance of a number of broad flat scales strung together on a delicate thread. Three typical forms are shown at fig. 13. No doubt the black brushes break into innumerable fragments, and are yet another modification of the dust-hair apparatus.

The clasper contains much cellular material, especially in the distal and marginal areas. It is of the same type as that in the clasper of *Lepyrodes neptis*.

Pachyzancla licarsisalis Wlk. (5151).

The fore-wing costa is densely clothed with scales for about half its length, and these curl over towards the underside. They have the appearance of scent-scales. I have found no special organs on the thorax, but the armature has two lateral brushes, arising from just behind the bases of the claspers. These are formed from slender hairs, broadened at the distal ends into a spatulate form. In the preserved examples I have found great difficulty in making an expanded preparation of the whole system, as the brushes disintegrate at the least touch, though I do not think they act as dust-hairs, of the presence of which there seems no indication. Sections of the whole distal end of the abdomen show the usual relationship between the claspers and the brushes, but there is a notable absence of anything like glandular tissue at the sockets of the brush-hairs. Stained and cleared examples of the clasper show a great development of "sensory pits" along the margin, with a well-developed nerve supply, but little or no cellular structure. If there is any secretory apparatus associated with the brushes in this species I have been unable to identify it.

Pionea leucanalis Swinh. (5207).

The most striking feature of this species, of which only one example was available, is the densely hirsute tibia of the mesothoracic legs. Plate 3, fig. 14, shows the appearance of the leg cleared and mounted whole. In the condition of inactivity the tibia has a merely thickened appearance, due to the long hairs lying closely packed along its length. On opening out the structure with needles, a deep groove is found, the outer part of which is covered by a brush of fairly stiff hairs, whilst the groove itself is packed with long slender hairs, varying from ·002 mm. to ·008 mm. in diameter, and all constricted at intervals to form a mass of dust material. At *b*, fig. 14, is the brush proper, which at rest covers most of the tibia. At *c* are a few of the slender dust-hairs protruding from the groove. As one of the legs was mounted whole, only one was available for sectioning, and sections in one direction only do not fully show the arrangement. I have not been able with certainty to identify the sockets of the dust-hairs, but they appear to arise from the cuticle lining the groove, and there is no very evident glandular development. It is quite otherwise with the sockets of the stiffer hairs of

the brush *b*, which arise from a concavity of the tibia, near its junction with the femur. Beneath each socket is a large, more or less pyriform cell, which takes an intense blue with Mann's stain, whilst beneath and between these there are smaller cells which stain red, with bluish nuclei. Evidently the impregnation of the dust-hairs arises from this source. At fig. 16 I have shown a fragment of a section of these structures. The dust-hairs vary greatly in thickness and in the length of the segments. A few examples are shown at fig. 15. The narrowest are about ·002 mm. and the broadest about ·01 mm. in diameter.

Having only one specimen I cut the armature into longitudinal sections. This method gives little idea of the structure of the claspers, but it shows the presence of two well-developed lateral brushes lying against their outer surfaces. At fig. 17 I have shown the basal parts of a few of the brush-hairs. The sockets are of simple character, and the glandular development quite elementary.

Explanation of Plates.

Plate 1.

Fig. 1. *Glyphodes bivitralis*. Side view of head and prothorax. *b*, the brush. *m*, the membranous bag;
2. do. Section of the tissue of fold in which the brush lies;
3. do. View of anterior parts of insect with the brushes expanded;
4. do. Fragments of the dust-hairs;
5. *G. indica*. Extremity of abdomen;
6. *G. bivitralis*. Clasper;
7. *G. vertumnalis*. Hind tibia;
8. *G. negatalis*. Hairs of the "core" brush;
9. *G. hilaralis*. Anal brushes;
10. *Amyna* (*Ilattia*) *octo*. Armature and appendages;
11. do. Chitinous structures from intraharpal process;
12. *Nanaguna breviuscula nigridisca*. Side view to show position of brushes. *ts*, opening of tympanic sense-organ. *v*, vortical base of first abdominal brush;
13. do. Diagram of anal brush system. *a*, central mass of scales. *bb*, extrusible brushes. *ss*, swellings containing auxiliary brushes. *ab*, second abdominal brush;
14. do. Armature. *u*, uncus. *pp*, processes;
15. do. Upperside of right hind-wing. *p*, scent-scales.

Plate 2.

Fig. 1. *Polydesma umbricola.* Lateral view of metathorax. *o*, operculum of tympanic organ. *b*, brush;
2. do. Section of brush. *m*, membrane. *t*, vacuolated tissue. *g*, glandular tissue;
3. do. Armature.
4. *Remigia frugalis.* Underside of head and anterior parts;
5. do. Hind-leg;
6. *Thalassodes veraria.* Hind-leg. *m*, fine hairs. *h*, tuft of scales. *t*, brush;
7. *R. frugalis.* Hair of brush. *h*, basal part of hair. *s*, socket. *ct*, cytoplasmic material. *c*, cellular layer. *cu*, cuticle;
8. *T. veraria.* Fragment of membrane from concavity of coxa;
9. do. Bases of two hairs from the "core" brush;
10. *Nephopteryx paurosema.* Organ on underside of hind-wing. *t*, spatulate scales. *b*, brush. *n*, nervure from which fold projects;
11. do. End of one of the wing-brush hairs to show folding;
12. *Cnaphalocrocis medinalis.* Fore-wing;
13. *Marasmia venilialis.* Section of the wing-organ. *sc*, scent-scale. *d*, dust-hairs. *s*, protective scales;
14. do. Clasper. *p*, process with sensory spines. *s*, scales (shown more magnified at fig. 15);
15. do. Scales from end of clasper;
16. *Botyodes asialis.* Dissection of end of abdomen;
17. do. Dust particles;
18. do. Sockets of three of the outer brush-scales;
19. do. Bases of dust-hairs and cellular layer beneath them.

Plate 3.

Fig. 1. *Lepyrodes neptis.* *c*, organ on underside of metathorax;
2. do. Cells from clasper;
3. do. Clasper;
4. *Crocidolomia binotalis.* Base of fore-wing. *t*, folded scales;
5. do. Fore-legs, brushes, etc., extended. *b*, brush. *c*, coxa. *s*, sheath;
6. do. Coxa more highly magnified. *cy*, scaled concavity. *p*, "plate" scales. *c*, deep concavity. *sp*, fine scales protruding from cavity;
7. do. Section of fragment of basal part of "neck-brush." *ch*, part of erectile apparatus. *h*, short-socketed hairs. *hh*, long-socketed hairs;
8. do. Section of brush-bearing part of coxa. *sc*, "plate" scales. *s*, fine hairs. *g*, glandular cells;
9. do. Fine hairs from interior of coxa;
10. *Eurrhyparodes bracteolalis.* Section of costal organ of fore-wing. *cn*, costal nervure. *cs*, covering scales. *dh*, dust-hairs. *sc*, scent-scales;
11. do. Fragments of dust-hairs from wing;
12. *Sameodes cancellalis.* Brush apparatus from terminal part of abdomen. *fb*, "fused" brushes. *bb*, black-scale brush. *c*, cuticle. *ob*, outer brush. *gl*, gland-cells;
13. do. Parts of scales from the black-scale brush;
14. *Pionea leucanalis.* Mesothoracic leg. *b*, brush. *c*, fine hairs protruding from interior of groove;
15. do. Fragments of dust-hairs;
16. do. Sockets of brush-hairs (*b*, fig. 14);
17. do. Sockets of armature brush-hairs.

Note. The magnifications vary. Some typical measurements are given in the text.

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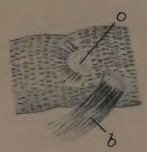
STRUCTURES IN INDIAN MOTHS.



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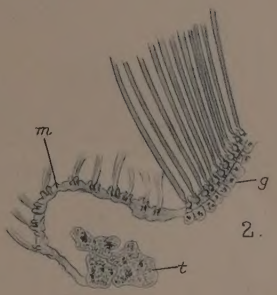

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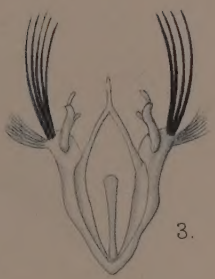
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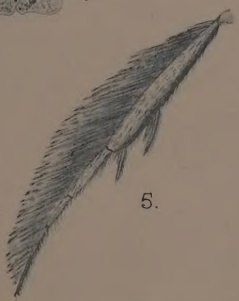
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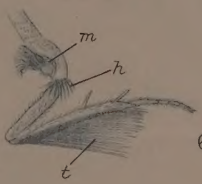

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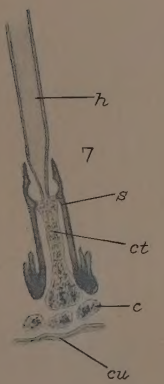

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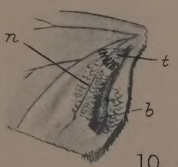

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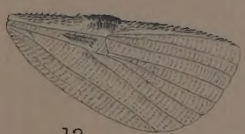
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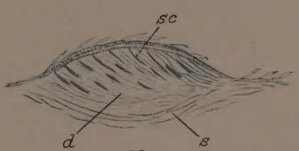

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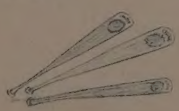
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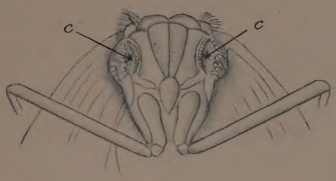

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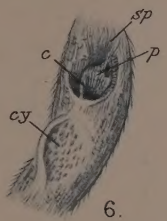

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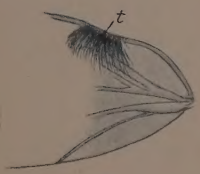

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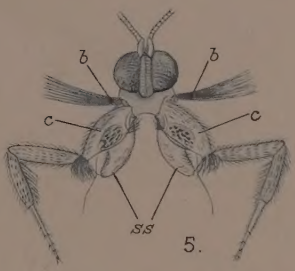

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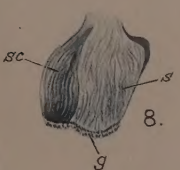

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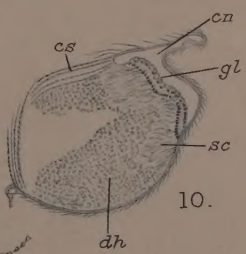

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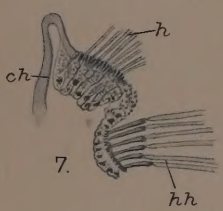

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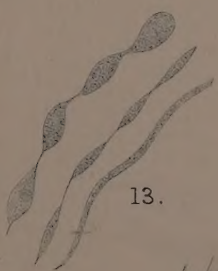

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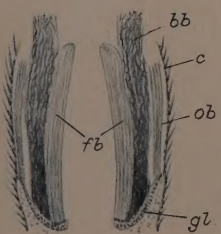

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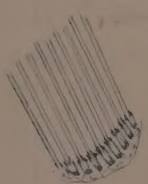

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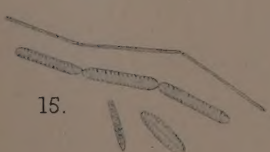

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